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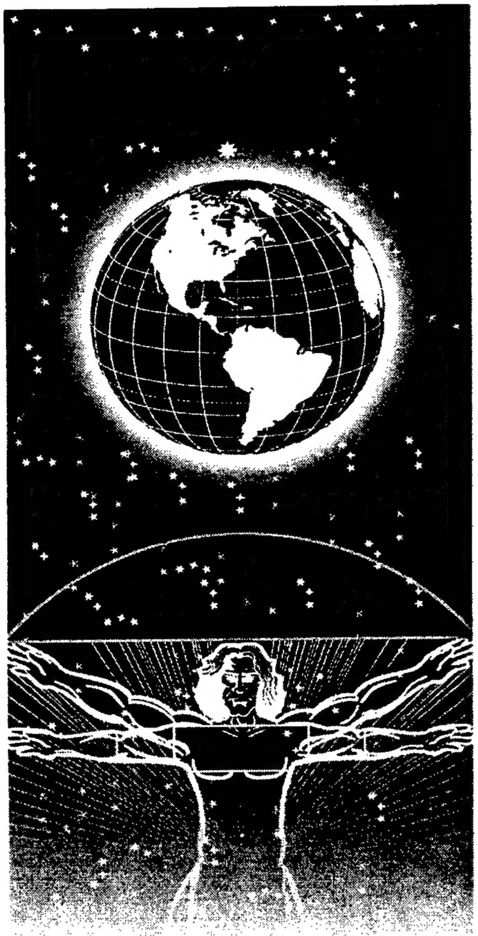

UNITED STATES AIR FORCE
ARMSTRONG LABORATORY

Demonstration of a Filter Cart for NOx Removal from Ground Support Equipment

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14. Abstract McClellan AFB, California, identified mobile diesel engines as contributing nearly as much oxides of nitrogen (NOx) emissions as aircraft and permitted stationary sources combined. Hourly-rated diesel engines contributed 75 percent of this NOx, with the remainder emitting from gasoline and diesel engines rated in miles. The Armstrong Laboratory Environics Directorate at Tyndall AFB, Florida, with the support of Applied Research Associates and Sorbent Technologies, has developed and demonstrated a simple and effective technology for reducing non-road diesel NOx and other air pollutant emissions. The filter cart was designed to control emissions of NOx, particulate, and unburned hydrocarbons (UHCs) from mobile diesel generators. It uses a simple vermiculite-based filter to capture particulate, a large air-to-air heat exchanger to cool the gas, a demister to remove condensable liquids, and rows of activated carbon (AC) filters to adsorb NOx and UHCs. A separate stand-alone system is used to desorb and destroy the contaminants adsorbed on the AC filters. Over 90-percent removals of NOx by the filter cart have been repeatedly demonstrated in the field.

15. Subject Terms

NOx Control, Diesel Exhaust, Activated Carbon, Filtration, AGE

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Abstract

McClellan Air Force Base (AFB), California, identified mobile diesel engines as contributing nearly as much oxides of nitrogen (NO_x) emissions as aircraft and permitted stationary sources combined. Hourly-rated diesel engines contributed 75 percent of this NO_x, with the remainder emitting from gasoline and diesel engines rated in miles. The Armstrong Laboratory Environics Directorate at Tyndall AFB, Florida, with the support of Applied Research Associates and Sorbent Technologies, has been demonstrating innovative pollution control technologies for several years at McClellan AFB, and has developed and demonstrated a simple and effective technology for reducing non-road diesel exhaust emissions of NO_x and other air pollutants. The filter cart was designed to control emissions of NO_x, particulate, and unburned hydrocarbon (UHC) from mobile diesel generators. It uses a simple vermiculite-based filter to capture particulate, a large air-to-air heat exchanger to cool the gas, a demister to remove condensable liquids, and rows of activated carbon (AC) filters to adsorb NO_x and UHCs. A stand-alone system has been designed to desorb and destroy the contaminants adsorbed on the AC filters. In this manner, the filter cart acts as a storage device for the pollutants. The test unit was designed to be nearly self-contained on a wheeled base, and is only slightly larger than the ground support generators. The filter cart has undergone extensive testing at McClellan AFB. Over 90-percent removals of NO_x have been repeatedly demonstrated in the field, with laboratory-scale desorption/destruction over 99 percent attained. This paper will present design specifications of the filter cart systems and results from field and laboratory testing. Important thermodynamic factors influencing the filter cart performance and recommendations for design improvements will also be discussed.

Introduction

The South Coast Air Quality Management District Rule 1110.2 threatened to regulate non-road mobile sources larger than 50 bhp as stationary sources. Much DoD support equipment falls in this category of hourly-rated non-road sources. Of particular concern were emissions from A/M32A-86 mobile diesel generators used for providing electrical power to aircraft while being serviced on the flightline.

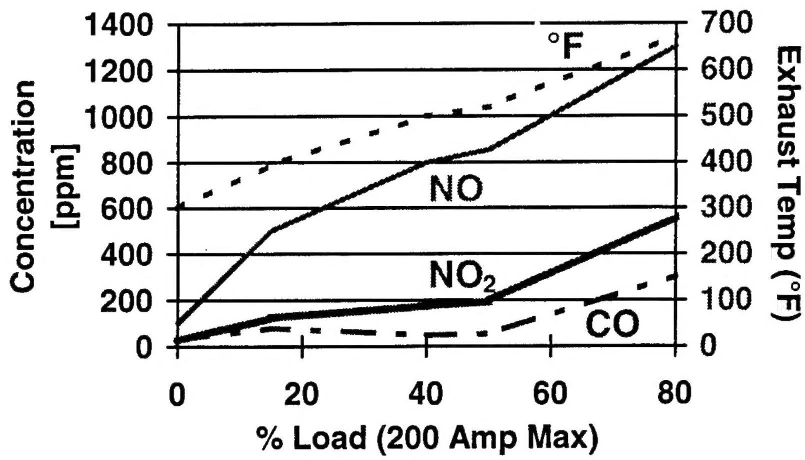

Figure 1: A/M32A-86 Diesel Generator Exhaust Characteristics Vs. Generator Load

The A/M32A-86 is powered by a 148 bhp diesel engine, and has exhaust characteristics shown in Figure 1. March ARB (formally AFB) in southern California operates over 50 of these generators, and was potentially faced with controlling emissions from the generators or ceasing their operation. The filter cart was identified as a potential technology to apply for air pollutant control from the A/M32A-86. Although significant emissions reductions have been attained through simply installing new injectors and delaying the timing of injection, the filter cart proved to be capable of efficiently controlling the air emissions from the A/M32A-86 [1]. The filter cart has also been successfully demonstrated on other sources [2].

Design Specifications and Components

A sketch of the filter cart is shown in Figure 2. Discussion of individual components follows:

- INLET: The inlet to the filter cart is connected to the combustion source with a flexible stainless steel duct. This cart was designed to process approximately 1000 actual cubic feet per minute (ACFM) of exhaust gas maximum. The primary design factor is linear velocity through the filter beds; all components are sized for the desired flowrate.
- PARTICULATE PREFILTER: The particulate prefilter is 36" long by 24" wide by 4" thick. It is made of coarse vermiculite contained by pads of commercial fiberglass filter material. The primary purpose of the prefilter is to prevent fouling of other components in the system, and secondarily for environmental purposes. The chamber is designed for the particulate prefilter to be removed as a drawer. As designed, the prefilter creates less than 4" H_2O pressure-drop (ΔP). Significant increase in dP across the prefilter is used as a criteria to replace the filter. Particulate removal tests determined 92.5 percent of coarse and over 99 percent of fine (less than 10 micrometer) particulate are removed by the prefilter. The fiberglass filters and vermiculite are disposable as a non-hazardous waste.

- HEAT EXCHANGER: An air-to-air heat exchanger is used to cool the exhaust gases down to the adsorptive range of the carbon filters (less than 150 °F, with improved adsorption at lower temperatures). The heat exchanger is over-sized with a ½-bhp motor to lower the exhaust gas as near to ambient temperature as possible. It will be shown later that ambient temperature is as critical to NO_x removal than hours of filters use.
- DEMISTER: An off-the-shelf demister is used to remove condensable liquids from the gas stream. Water vapor and other condensables would consume active sites in the carbon filters and reduce the capacity for NO_x adsorption.
- CONDENSATE DRAIN: A u-shaped pipe is used to allow condensate to drain from the demister without allowing gas to also escape the pipe. The flowrate of condensate is a function of the ambient relative humidity, since water vapor in the combustion gas is not consumed. Table 1 lists condensate constituents other than non-detect as analyzed by the Environmental Management Laboratory at McClellan AFB. The results indicate that, for combustion of military diesel in the A/M32A-86 generator, condensate from the NFC can be discharged to the sanitary sewer system (not classified as industrial waste). Figure 3 shows the increase in condensate drip rate with increasing ambient relative humidity.

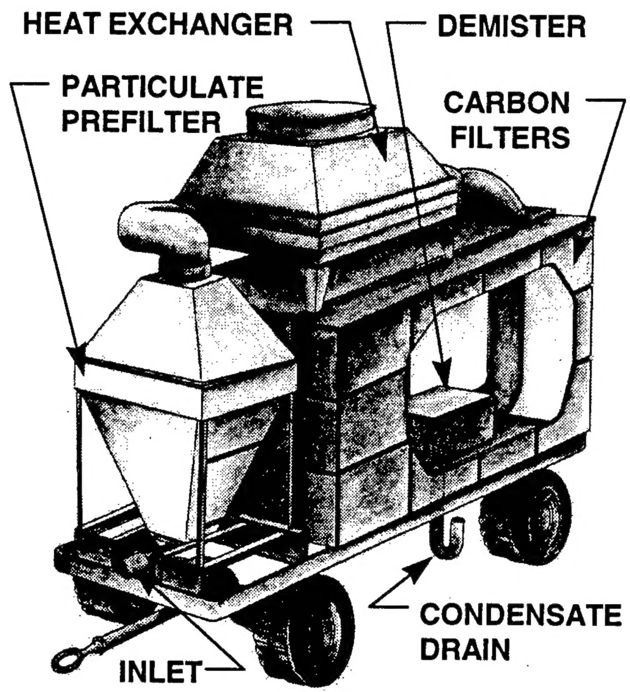

Figure 2: Sketch of Prototype Filter Cart

Table 1: Condensate Analysis (11 Jul 96)

EPA 502.1		EPA 503.1	
Compound	ppb	Metals	ppb
Benzene	3	Chromium	13
Tetrachloroethylene	3	Copper	750
Methyl ethyl ketone	19	Lead	84
Methyl isobutyl ketone	3	Nickel	43
Acetone	212	Zinc	750

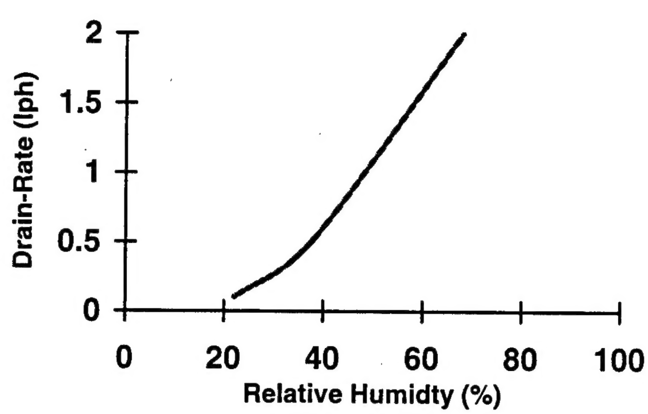

Figure 3: Condensate Drip-Rate Vs. Ambient Relative Humidity

- CARBON FILTERS: The filter cart has 24 individual filter beds (2 sides of three 4-filter rows). Each filter is 21.5" wide by 14" tall and 8" thick. This cart was designed with filters small enough to allow one person to easily remove and replace the filter. The 2nd - generation design (discussed later) will involve large, enclosed filters and allow regeneration in-place.

Application of the filter cart on an A/M32A-86 generator at McClellan AFB is shown in Figure 4.

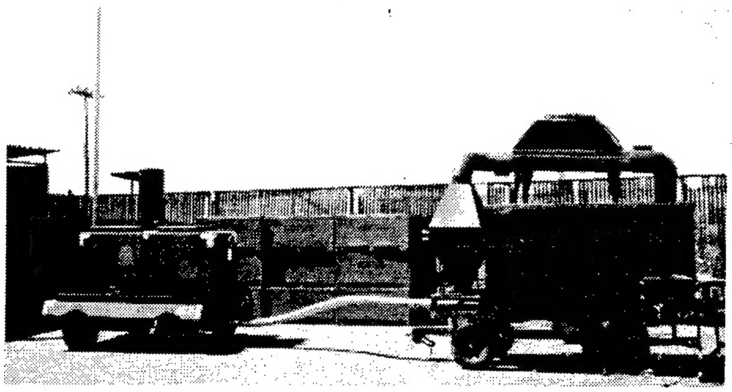

Figure 4: A/M32A-86 Diesel Generator Connected to Filter Cart

Factors Affecting Performance

The effect of ambient relative humidity on the condensation drip-rate was mentioned earlier. Without a demister, this water vapor would reduce the adsorptive capacity of the carbon for NO_x, CO, and UHCs. Ambient temperature is even more critical, as depicted in Figure 5.

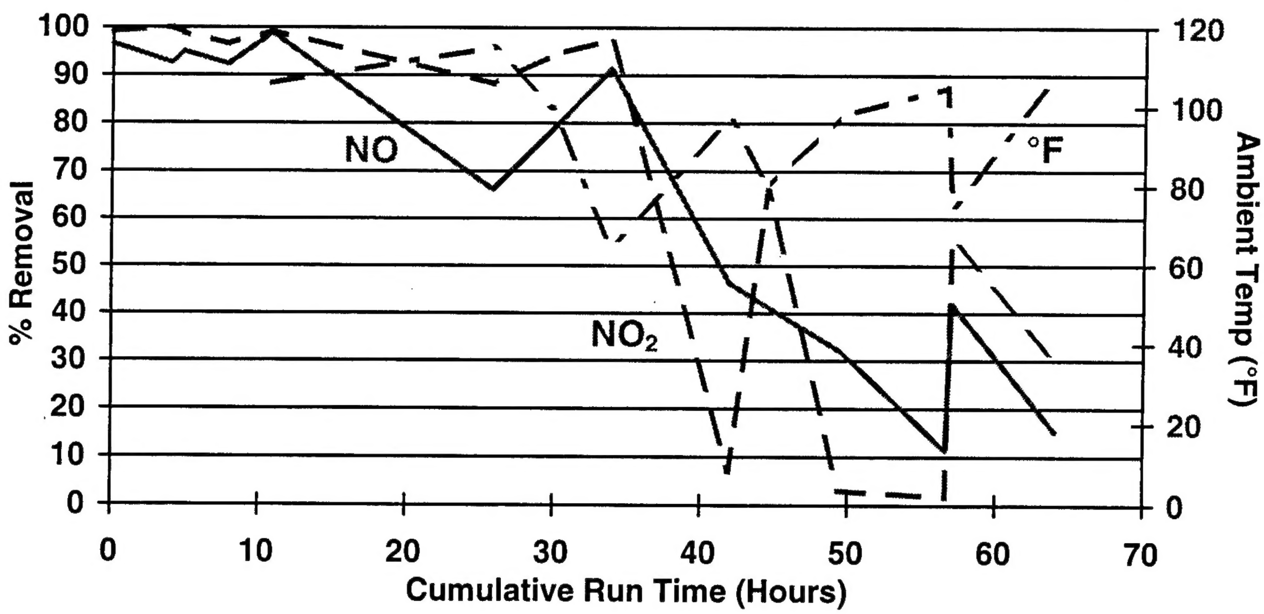

Figure 5: NO and NO_2 Removals Vs. Time and Temperature

Figure 5 charts the NO, NO_2, and CO removal over time on the left y-axis, and ambient temperature on the right y-axis. Given the physical nature of the adsorption process, it would be expected that these rates would fall off rather linearly or slightly logarthimically with time. Temperature is plotted in Figure 5 to correlate the excursions to low removals that occur at high ambient temperatures. With the air-to-air heat exchanger, the lowest possible temperature for the exhaust gas to reach is near-ambient. The activated carbon has less adsorptive capability at higher temperatures.

Regeneration and Reuse of Activated Carbon Media

The adsorption of NO_x, CO, and UHCs by the filter cart only completes part of the compliance solution. To effectively control emissions, these captured contaminants are destroyed off-line using a desorption-catalytic destruction system, as depicted in Figure 6. With the current design, the individual filters are placed in an oven and heated to over 300°F. A compressor and regulator controlled by a feedback monitor meter the gases driven off the carbon through a selective catalytic reduction reactor with small amounts of combustion gas added.

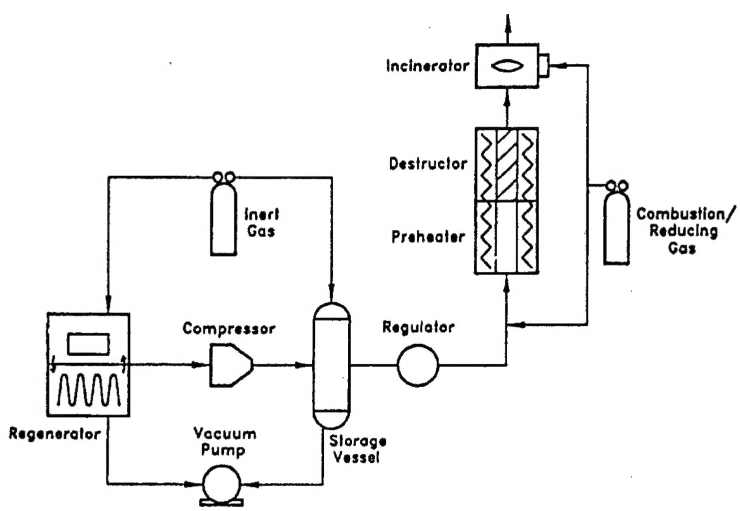

Figure 6: Activated Carbon Regeneration / NO_x, CO, UHC Destruction System

Future Design Considerations

Future designs planned include larger filter beds with in-place regeneration capability. This will streamline the continued use of the filter cart, since individual filters will not be manually handled. Improvements to the heat exchange system are planned, and numerous other refinements resulting from user feedback during demonstrations at McClellan AFB.

Conclusions

The NOx filter cart has demonstrated significant promise as an air pollutant control technology for small and medium-sized combustion sources. Continuing investigations will quantify the long-term operating costs of the sorption/desorption concept for NOx and other pollutant

capture and destruction. Future papers will document these findings.

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